THE APPLICATION AND ENERGY SAVINGS POTENTIAL OF OCCUPANCY COUNTERS/TRANSMITTERS IN OFFICE BUILDINGS

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ABSTRACT

In conventional office building design, fresh air requirements are estimated for full occupancy in the building. Typically, fresh air requirements range from 5 to 15 cubic feet per minute per person expected to occupy the building. While the design total amount of fresh air used is satisfactory for full occupancy of the building, there are many instances less than the design occupancy. Thus, there may be many instances in a commercial building where more fresh air is used than is actually required because the occupancy is below the design occupancy.

In hot and humid climates, such as the Gulf Southwest, a considerable portion of the cooling energy in a commercial building is expended cooling and dehumidifying the air needed to maintain fresh air requirements. If the total amount of fresh air could be reduced to just match that needed by the number of occupants in a building, it would be possible to reduce the energy use for cooling.

This paper summarizes the design and use of an occupancy counter/transmitter that can be used to count the number of people entering/leaving a building and make adjustments in the amount of fresh air used in the building. Sample economics of the system, including initial costs and savings are also provided.

INTRODUCTION

Several years ago when working on the design of an air conditioning system in a library that held several hundred people it was observed that air conditioning the ventilation air was a large expense. I searched for equipment to automatically control the ventilation air in accordance with the number of people in the library. Not being able to find any equipment suitable for this, I specified night setback on the thermostat but remembered the need for the instrument.

Several years later I decided to design and develop such an instrument because of the economic need for it; and these instruments are the result of that decision. If the proper amount of air for full occupancy is being supplied at all times and the occupancy varies considerably, a substantial amount of money can be saved when occupancy is low. Conversely, putting in only the air needed makes it more economically feasible to do an adequate job of ventilating when the occupancy is high.

EXPECTED SAVINGS

In order to illustrate the possible savings by using the occupancy counter (Pulse Adder Subtracter Difference Transmitter) some calculations follow based on temperatures and humidities which can be expected to occur in Houston, Texas.

SUMMER CONDITIONS

Table 1 - Data used for sample calculations for Summer conditions

Item	Value
Outside dry bulb temperature*	84.2 degrees F
Outside dew point temperature*	71.7 degrees F
Outside relative humidity*	54 percent
Outside air ventilation	1000 cfm (71.28 lb/min)
Inside air temperature	75 degrees F
Inside relative humidity	50 percent

*Average for hours 7 AM to 7 PM for month of August

Under the above conditions, the building would require 2.54 tons of refrigeration to adequately cool and dehumifiy the ventilation air. If the cooling equipment uses 1 kW/ton and electricity cost $0.10 per kWh, then the hourly cost of conditioning the ventilation air would be $0.254.

EQUATIONS

lbs of oa brought in per min = 1000/14.03 = 71.28 (1)

enthalpy of oa brought in per min = 71.28x35.52 = 2531.9 Btu (2)

enthalpy 1000 cfm of oa after being brought to inside (3)

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conditions of 75 degrees F&50% rh = 71.28x28.4 = 2024.4 Btu

Btu per minute chargeable to ventilation air = 2531.9 -2024.4 = 507.5 (4)

tons of refrigeration required = 507.5/200 = 2.54 (5)

kW requirred at 1 kW per ton = 2.54 (6)

For the average office building in Houston this serves about 100 people. Compared to putting in ventilation air continuously for full occupancy, this is the approximate saving for each 100 less than full occupancy each hour. For a 10 hour day this amounts to $2.54 and for the month of August with 21 work days it amounts to $53.34.

WINTER CONDITIONS

Table 2 - Data used for sample calculations for Winter conditions

Item	Value
Outside dry bulb temperature*	40 degrees F
Outside relative humidity*	90 percent
Outside air ventilation	1000 cfm (78.80 lb/min)
Inside air temperature	75 degrees F
Inside relative humidity	50 percent

* Arbitrarily assumed

Under the above conditions, the building would require (64.77/efficiency of heating system) cubic feet of gas per hour to adequately condition the ventilation air. If the gas costs $10 per thousand cubic feet, then the hourly cost of conditioning the ventilation air would be $0.648/efficiency of heating system.

EQUATIONS

Lbs of oa brought in per minute = 1000/12.69 = 78.8 (7)

Enthalpy of oa brought in per minute = 78.8x14.7 = 1158.4 Btu (8)

Enthalpy of 1000 cfm of oa after being brought to inside conditions of 75 degrees dbt & 50% rh = 78.8x28.4 = 2237.9 Btu (9)

Btu per minute chargeable to ventilation air = 2237.9-1158.4 = 1079.5 (10)

Btu per hr chargeable to ventilation air = 1079.5x60 = 64,771.2 (11)

Cu Ft of gas per hr of operation = 64,771.2/1000 X efficiency of heating system = 64.77/efficiency of heating system (12)

Cost of gas per hr at $10 per 1000 cu ft = 64.77 X10/1000X efficiency = $0.648/efficiency of heating system (13)

For the average office building in Houston, this serves about 100 people. Compared to putting in ventilation air continuously for full occupancy this is the approximate savings for each 100 people less than full occupancy each hour. For a 10 hour day this amount to $6.48/efficiency and for a month of 21 working days it amounts to $136.08/efficiency of the heating system.

It is realized that the figures of $0.10 per kW hour and $10.00 per 1000 cubic feet of gas are high but using these figures makes it easy to correct for the cost at any particular location.

PRINCIPLES OF OPERATION

There are two types of equipment: Electropneumatic and electronic.

All equipment is designed to work with any brand of controller that accepts standard signals.

The electropneumatic transmitters operate on 115 Volt AC and put out a pneumatic signal directly in proportion to the added number minus the subtracted number divided by the full scale number of the instrument. If the instrument system operates on a different pressure range, a standard pressure multiplyer or divider can be furnished to bring the pressure to the desired range. If the final control element has linear characteristics with respect to the air flow being brought in, no additional controller will be required; and the transmitter can control the final element directly. However, in most instances a controller with velocity feedback is needed to obtain accurate control.

The electronic transmitters operate on any AC Voltage and frequency that meets one of the international standards for use in buildings and puts out a standard milliampere or Voltage signal. The output is directly proportional to the added number minus the subtracted number divided by the scale of the instrument. If the final control element does not have a linear relationship with the incoming air velocity, it will be necessary to feed the transmitter signal to a controller with velocity feedback to get accurate control.

ILLUSTRATION

Figure 1 is made for a typical office building in Houston using average temperatures for the month of August and average occupancy per hour from 7AM to 7PM. This would only be correct for buildings with very low infiltration and exfiltration.

With either the pneumatic or electronic system the controller can

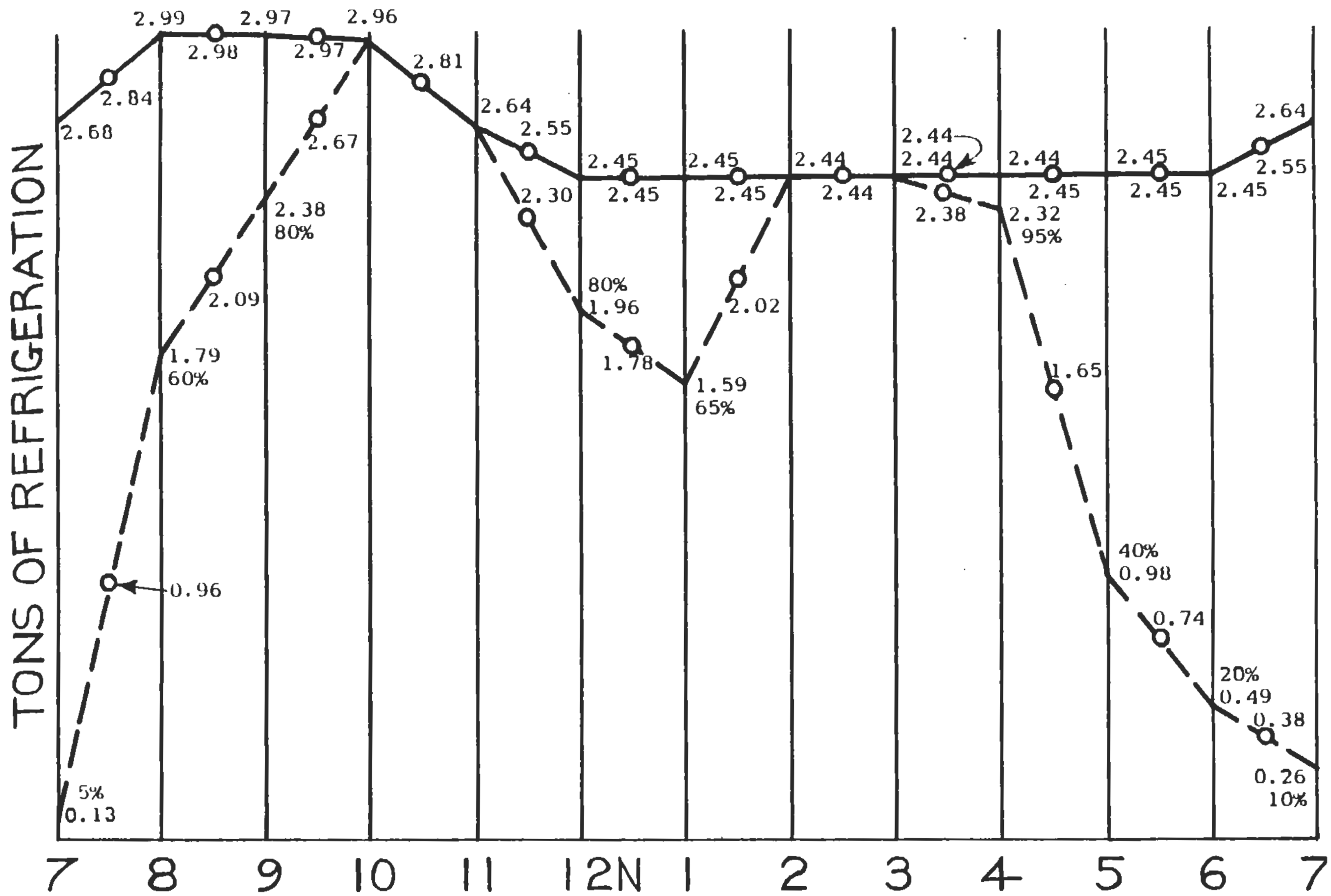

Figure 1 - Showing savings for a typical office building in Houston, Texas for an average August day. Solid lines show tons per 1000 cfm of outside air. Dashed lines show solid lines times fractional occupancy. Circles show average tons for hour. Percent symbol shows percent occupancy. Savings = area under solid lines minus area under dashed lines = 34.02 - 22.22 = 11.8 or 35%.

control any type of final element: damper motor with positioner, variable speed fans, variable pitch fans, fans with inlet or outlet vanes, variable speed electric motors for fan drives, pressure switches, meter relays, etc. by using electric to pneumatic or pneumatic to electric transducers.

This system is not connected to the controls of the air conditioning system in any way except the part bringing in outside air and venting the same amount of inside air to the outside. The only way it will affect the operation of the air conditioning system is by reducing the power consumption when less outside air is brought in.

ELECTROPNEUMATIC OCCUPANCY COUNTERS

The electropneumatic counter (Pulse Adder Subtracter Difference Transmitter) is based on an Add Subtract Stepper Relay modified to drive a Lead Screw and a Pressure Regulator that is not highly accurate unless calibrated after assembly. The uncalibrate unit could have an error of + or - 10 percent but the reproducibility error is much less probably close to + or - 0.5 percent. These units are intended for controlling the ventilation air in buildings, auditoriums, etc., based on the number of people in the enclosure or other applications where great accuracy or high speed adding and subtracting is not required. The maximum speed of these units is 29 steps per second and they operate off of 120 VAC with one pulsing switch for adding and one for subtracting. They have an add and a subtract switch built in for initial setting or for bringing the unit to zero count if it gets off for some reason, such as people going out a side door for example.

ELECTRONIC OCCUPANCY COUNTERS

These counters (Pulse Adder Subtracter Difference Transmitters) are completely solid state except for a plug in relay in the add pulse line. These relays are for the purpose of isolating the electronic system from any voltage spikes which might occur in the line feeding the pulses into the transmitter.

The transmitter contains equipment to hold the signal at the maximum value if the difference goes above the maximum number the instrument is designed for, and to hold the signal at a value representing zero if the subtract pulses exceed the add pulses.

The electronic circuitry is based on the 8 bit binary system and for this reason the output occurs in 255 equal increments. The numbers above 255 are obtained by dividing the incoming pulses by a whole number from 2 to 10. For this reason, the instruments will have a deadband equal to the divisor.

ADDER SUBTRACTER TRANSMITTERS

These transmitters are made for controlling the make up air to laboratories in proportion to the amount taken out by exhaust hoods or for other purposes which have a relationship to motors or other equipment running.

Each transmitter is made for a specific number of fans starting with 2 and is adjusted for the capacity of each fan. The number of fans is limited by the ability of the controlled equipment to follow the output signal with a linear relationship of capacity to signal. The fans may be started in any sequence.

These are electronic type instruments that can operate on any AC Voltage and frequency that meets one of the international standards for use in buildings, and they put out a standard milliampere direct current or direct current Voltage signal. The transmitter receives its signals from an auxiliary set of contracts in each motor starter, preferably normally open contacts or special contacts for signaling the adder subtracter transmitter.

EXTRA COSTS

The extra cost of equipment in the building for a control system will vary from approximately $4000 to $10,000 depending primarily on the type and size of the final device being controlled; such as dampers, slide gates, variable speed motors, etc.